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Forensic Anthropology Population Data

Age estimation of Hispanic children using the London Atlas

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ABSTRACT

Purpose: To test the accuracy of the London Atlas for age estimation of Hispanic children and to determine if there is any difference in age accuracy between Hispanic males and females.
Methods: The London Atlas was used to estimate age from panoramic radiographs of 17 males and 17 females for each year of age from six to 15.99 years, using the electronic patient database of a dental school. Exclusion criteria included gross pathology, hypodontia, hyperdontia, and previous orthodontic treatment.
Results: There were 332 panoramic radiographs evaluated. In all age groups, 34 radiographs (from 17 males and 17 females) were reviewed, except for the age bracket 6–6.99 years, for which only 26 radiographs were available. The mean age estimated of the entire sample by the London Atlas (11.44 years) was greater than the mean chronological age (11.09 years), which was statistically significant ($P < .001$). The mean difference between chronological and estimated ages for males was .30 years and for females was .40 years, but the difference between sexes was not significant ($P = .324$). One hundred sixty-two radiographs (49%) were estimated to the exact age interval while 45 (14%) were under-estimated and 125 (38%) were over-estimated. Two hundred and forty radiographs (72%) were estimated to a value within one year of the actual age.
Conclusion: There was no difference in age estimation prediction accuracy between Hispanic males and females but an age overestimation of three percent in the cohort was seen. The London Atlas accuracy is suitable for use in forensic investigation.

1. Introduction

Age is the key factor that determines a person's eligibility to participate in and receive support from various social services, attend school, and seek work. Human age serves as a metric and contributes to how the justice system handles cases involving adoption, asylum seeking, child abuse, child labour, child marriage, disaster response, forensic identification, human trafficking, immigration, and kidnapping. Age can also be used to determine if a case belongs in juvenile or adult court. It is an important characteristic in the anthropological and forensic dentistry processes in the identification of bodies during disaster response and genocide events.

Currently, dentition analysis is a suitable system for age estimation of humans. Human tooth formation exhibit less variation than stages of skeletal maturation [1]. Childhood diseases tend to have less effect on the human dentition and exert less effect than on secondary sexual characteristics, height and bone age [2,3]. The effect of nutrition, modifying height and bone age, is more significant than on tooth formation [1]. Anthropological and forensic data demonstrate teeth are often the most preserved tissues of deceased individuals [4]. In summary, the Study Group on Forensic Age Diagnostics recommends that a forensic age estimate should consist of a physical examination, a radiograph of the hand, and a dental examination, including evaluation of a panoramic radiograph if available [5].

One of the most widely referenced representations of the developing dentition is found in the research and dental charting accomplished by Schour and Massler [6]. This landmark research paper contained 22 drawings representing the development of the

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human dentition, ranging from five months in utero to 35 years of age. Shour and Massler leveraged previous research published in 1933 by Logan and Kronfeld [7], who published a Chronology of the Human Dentition chart that has served as a reference for subsequent researchers. Ubelaker [8] modified the Schour and Massler chart his landmark 1978 research and analysis of the bones and teeth of Native American Indians. These two atlases by Schour and Massler [6], and Ubelaker [8] provide the modern dental investigator and researcher with a rapid, pictorial-based, descriptive metric for each stage of tooth development and then assigns a representative age that can best match the currently accepted dental age estimations.

Nolla [9] devised a dental age system with eleven developmental stages, including a method of tooth crypt staging before initial calcification. Gleiser and Hunt [10] created a thirteen-stage system in 1955 and the stages of tooth formation by Moorrees et al. [11] are widely recognized by researchers. Demirjian et al. [12] developed an eight-stage system in 1973 based on the analysis of French-Canadian children. Their system assigned each stage of tooth development a numerical value that could be incorporated into an equation to calculate the dental age. Willems et al. [13] expanded Demirjian et al.'s method of staging tooth development with their analysis of dental data from Belgian children. Radiographic imaging of dental structures employed by Cameriere et al. [14] measured the dimensions of teeth on a radiograph to estimate age.

To date, there is not one universally accepted method for dental age estimation because there is no single anthropological or dental analysis method proven to be superior. There is also controversy with respect to whether estimation tools should be population specific. Liversidge [15] considered the variation *within* a population (biological differences) to be greater than the variation *between* populations, therefore suggesting that having population specific dental age estimation methods is unnecessary. Dental age determination and staging, within populations, and with respect to timings in tooth development, continue to be debated in global research venues. The research community continues to study and correlate dental age data and staging with new emerging data derived from dental genomics, with many researchers suggesting the body of evidence is yet to mature and develop with a standardized metric.

AlQahtani et al. [16] published a new dental age estimation method in 2010. The London Atlas (Queen Mary Innovation Ltd, London, United Kingdom) is a pictorial book that requires the investigator to assess the stage of formation and eruption for each tooth, and then match it to one of the 31 illustrations of age categories representing both tooth formation and tooth eruption. The tooth formation stages were adapted from Moorrees et al. [11] research and the eruption stages determined by research by Bengston [17]. The London Atlas was initially tested on subjects of British and Bangladeshi ethnicity, which showed it to be more accurate than the Schour and Massler's and Ubelaker's methods, and potentially more accurate than Demirjian's calculations. With the London Atlas's potential for better accuracy, a software version of the Atlas was developed, enabling a rapid age estimation methodology for a trained investigator.

The objectives of this study were to test the accuracy of the London Atlas for age estimation within a group of Hispanic children. A second goal was to determine if there was any difference in age accuracy between males and females within the same cohort. Two hypotheses were tested: (1) there is no difference between the chronological age and the dental age of Hispanic children estimated by the London Atlas, and (2) there is no difference in the accuracy of age prediction between Hispanic male and female children by the London Atlas.

2. Materials and methods

This study was a retrospective cross-sectional review of records of healthy Hispanic children from ages six to 15.99 years who had digital panoramic radiographs taken at the University of Illinois at Chicago (UIC) College of Dentistry (COD), Chicago, Ill., USA, between January 1, 2000 and January 15, 2016. The exclusion criteria were unclear and/or distorted radiographs, and patients who had previous orthodontic treatment and/or severe malocclusion, hypodontia, hyperdontia, and gross pathology (e.g., taurodontism, microdontia, amelogenesis imperfecta, dentinogenesis imperfecta, tumors, abscesses, fractures, etc.). The UIC Institutional Review Board approved the study (number 2016-0071).

A report of all patients who self-declared of Hispanic ethnicity or as Spanish-speaking in the COD electronic patient database (aXium, version 6.01.02.830, Exan, Coquitlam, BC, Canada) was generated. The principal investigator (PI), a paediatric dental resident who was trained in the use of the London Atlas, screened all records for the exclusion criteria. The radiographs that satisfied the study criteria were exported to a secure folder and were assigned an identification number by a random number generator program (RANDOM.ORG, Dublin, Ireland). The PI recorded the number on a spreadsheet (Excel, version 16.0.7571.7095, Microsoft, Redmond, Wash., USA) together with the patient's sex and age at the time of the radiograph.

Chronological age for each subject was calculated by subtracting the date of the radiograph from the date of birth after having converted both to a decimal age using Eveleth and Tanner's method [18]. The PI was blinded to the chronological age until after the age estimation was completed by keeping this information in a separate spreadsheet during data collection. The panoramic radiographs as well as the record of age and sex were stored in separate secure, password-protected folders.

The left maxillary and mandibular teeth were evaluated to determine their developmental and eruption stages according to the technique described by AlQahtani et al. [16]. The PI entered each stage on a table (Fig. 1) and the London Atlas software (https://atlas.dentistry.qmul.ac.uk/?app=1) generated the estimated age. The software has options for mixed sex diagrams and for sex specific diagrams, which were used in this study. The sample size was calculated using single mean estimation with standard deviation (SD) of 14 units in maturity score and precision of five units.

Prior to the beginning of data collection, the PI scored 34 randomly selected radiographs from all age groups twice in an interval of one week. A second investigator also scored the same radiographs. The inter- and intra-examiner reliability were tested using Cohen's Kappa, and IBM SPSS (Version 22.0, IBM SPSS Statistics, Armonk, NY, USA) was used for all statistical analysis. Estimated age was compared with chronological age for each subject. The chronological age was subtracted from the estimated age; a positive result indicated an overestimation and a negative result an underestimation. This difference, as well as the absolute difference for each radiograph, was tabulated.

The absolute difference assessed the range of the accuracy by removing the cancelling effect of equal, over- and under-estimation. The mean difference, mean absolute difference and standard deviation for each chronological age year interval were compiled. The radiographs were also categorized as having estimated ages within six, 12, or over 12 months of the chronological age. The chronological and estimated ages for the entire sample were compared using a paired t-test ($p < .05$ was considered statistically significant). The mean difference in chronological and estimated ages was compared between males and females using an unpaired t-test ($p < .05$).

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